NORTH ATLANTIC MODELING WITH MULTI-LAYER PRIMITIVE EQUATION MODELS: DAMEE-NAB

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LONG-TERM GOALS

To perform a realistic, fully eddy-resolving, wind- and buoyancy-forced numerical simulation of the North Atlantic basin with the Miami Isopycnic Coordinate Ocean Model (MICOM) (Bleck and Chassignet, 1994) with data assimilation capabilities.

OBJECTIVES

a) To evaluate the model's performance in reproducing the oceanic circulation, with a special focus on the coastal regions;
b) To evaluate the model's forecast skills and usefulness in providing boundary conditions for regional models.

APPROACH

A series of numerical models of increasing complexity and resolution is used to (a) evaluate the model's forecast skills and (b) develop an understanding of the interaction between the ocean interior and the coastal regions.

WORK COMPLETED

a) 6-year integration of the high resolution (1/12°, mesh size on the order of 6 km) North Atlantic DAMEE-NAB (Data Assimilation and Model Evaluation Experiment - North Atlantic Basin) experiment (Chassignet et al., 1997; Garraffo et al., 1997; Paiva et al., 1997; http://www.rsmas.miami.edu/groups/micom.html).
b) Several process studies on boundary current separation and gyre dynamics (Griffa et al., 1996; Stern et al., 1997, Ozgokmen and Chassignet, 1997; Ozgokmen et al., 1997).
c) Data assimilation capabilities for MICOM (Chin et al., 1997b)

RESULTS

The Miami Isopycnic Coordinate Ocean Model (MICOM) has been configured for the North Atlantic (28°S-65°N) (Figure 1) with a horizontal resolution of 1/12° (mesh size on the order of 6 km) and 16 layers in the vertical. Such a setup demands the latest in high performance computing (Bleck et al., 1995). Each time that the horizontal resolution is increased by a factor of n, the computational load goes up by a factor n^3, since the n-fold reduction in linear mesh size requires n times more time steps to integrate the model over a given time interval.

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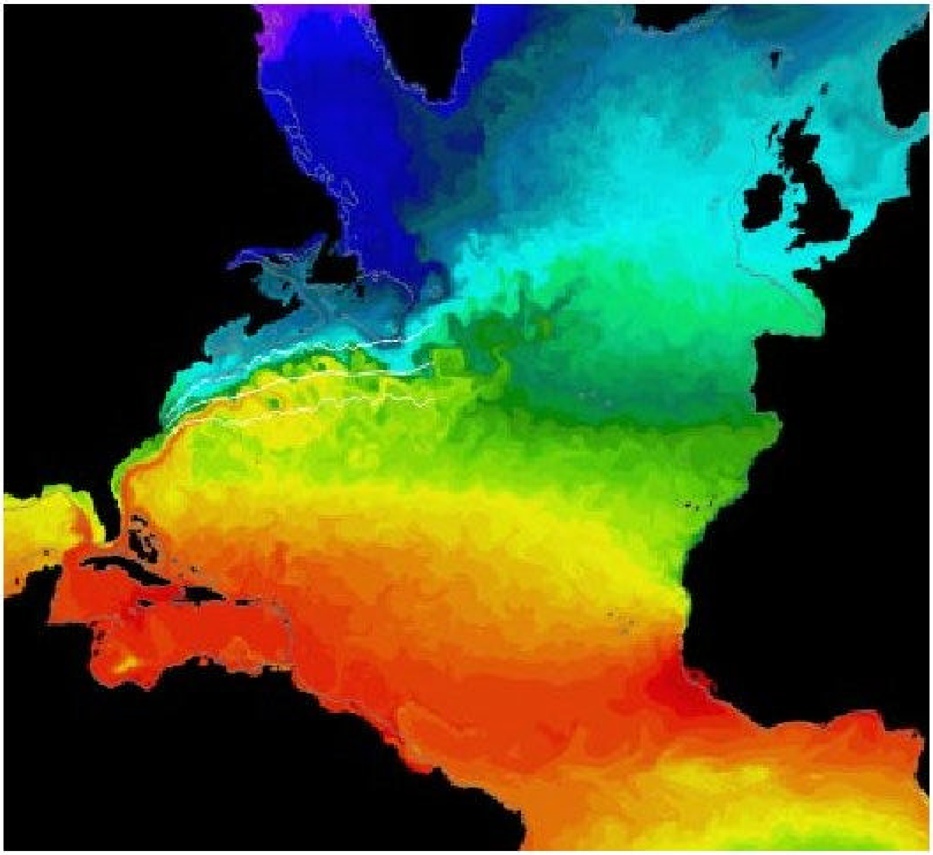

Figure 1: Model SST field year 5 day 300 (red denotes warm temperatures, blue cold Temperatures). The observed mean position of the Gulf Stream is represented by the dotted line. The envelope is defined by the solid lines.

The surface boundary conditions are based on seasonal climatological data sets (COADS) (DaSilva et al., 1994). Open ocean boundaries are treated as closed, but are outfitted with 3-degree buffer zones in which temperature T and salinity S are linearly relaxed toward their seasonally varying climatological values (Levitus, 1982). These buffer zones restore the T and S fields to climatology in order to approximately recover the vertical shear of the currents through geostrophic adjustment. The restoring time scale varies from 30 days at the inner edge, linearly decreasing to 5 days at the walls. The vertical grid was chosen to provide maximum resolution in the upper part of the ocean.

In this configuration, a realistic result for the Gulf Stream separation is achieved as illustrated in Figure 1. This result supports the view that an inertial boundary layer (which results from the fine resolution) is an important factor in the separation process (Ozgokmen et al., 1997). In this paper, the joint effects of (a) coastline orientation, (b) bottom topography, and (c) inertia on the mid-latitude jet separation were investigated in a two-layer wind-driven quasi-geostrophic model. It was shown that topographic effects are of importance in high eddy activity regions and that eddy-topography interactions strongly influence the separation process. In order for the western boundary current to separate from the coastline and cross the *f/h* contours associated with the continental rise, eddy fluctuations need to be weak at the separation point. This can be achieved either by introducing a positive wind stress curl in the northern part of the domain or by increasing the inertia of the western boundary current. In both cases, the separation is facilitated by low eddy activity, resulting in a decoupling of the upper layer from the lower layer when the current crosses the *f/h* contours.

The turbulent behavior of the fine mesh simulation has been assessed by Paiva et al. (1997). Sea surface height variability spectra in the North Atlantic subtropical gyre were computed from the model results and compared to observations and previous models, within the framework of the geostrophic turbulence theory. Despite higher eddy activity and a correct Gulf Stream separation, there is no geographic variation in spectral slope in the inertial ranges as in previous simulations with coarser resolution. Observations, on the other hand, show a flattening in the spectra derived from altimeter data when moving from the western to the eastern side of the Atlantic. The surface forcings used in this simulation are based on monthly climatologies which resolve only the seasonal cycle and spatial scales on the order of several hundred kilometers. Consequently, mechanisms such as fluctuations in wind forcing on the spatial and temporal scales of atmospheric fronts and eddies are not represented in these simulations. The model SSH variability only reflects the contribution from the internal oceanic instabilities. The impact of high frequency wind forcing is presently being investigated in the last 4 years of the 10-year integration, in which the wind field consists of a superposition of monthly COADS data, ECMWF (European Center for Medium-Range Weather Forecasting) synoptic scales variability, and high frequency synthetic wind stress variability based on ERS-1 scatterometer statistics (Chin et al., 1997a).

Another strong focus of the research performed at RSMAS is real-time forecasting of both Eulerian fields, such as temperature and velocity, and Lagrangian trajectories. The five primary components of this research are (i) MICOM, the Miami Isopycnic Coordinate Ocean Model, (ii) satellite-derived sea surface temperature and height fields and data from Lagrangian drifters, (iii) an Extended Kalman Filter (EKF) with a second-order Gauss-Markov Random Field (GMRF) model for spatial covariances, (iv) a random flight turbulence model for Lagrangian trajectory prediction, and (v) contour-based parameter estimation and assimilation techniques. Most of the research activites are focused on the North Atlantic Ocean in the framework of DAMEE-NAB.

Assimilation of satellite-derived sea-surface temperature (SST) (36 km mesh size, 4 day composite) was performed by using the satellite-derived SST (instead of the climatological ship-observed SST) in the heat flux surface boundary condition of the 1/2° DAMEE North Atlantic simulation. These experiments yielded very encouraging results such as improved Gulf Stream separation. The latest Topex/Poseidon (T/P) assimilation experimentwas atwin-experiment, four layer, 100 x 100 horizontal grid points, wind-driven and highly nonlinear, double-gyre MICOM simulation for one year. Our EKF using a 2nd-order GMRF model was stable for one year with an exponential decrease in forecast error and was able to recover from a worst-case flat ocean initial condition with 6 months of simulated T/P data (Chin et al., 1997b). The next step is assimilation in the fine resolution DAMEE run. Coupling of the model to coastal, atmospheric, ice, and biological models has also been initiated.

IMPACT/APPLICATIONS

This research has potential for providing large scale information needed as boundary conditions for regional models as well as forecasting skills.

TRANSITIONS

The data from the 1/12° run are presently being analyzed in collaboration with observationalist W. Johns.

RELATED PROJECTS

Collaborations are active with DAMEE-NAB participants as well as with ONR sponsored PIs: R. Bleck, M. Chin, A. Griffa, W. Johns and A. Mariano.

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